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TELEVISION RE-BROADCAST LINKS: alleviation of off-set co-channel interference by means of simple video notch filters

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Summary

The subjective visibility of co-channel interference on television pictures may be reduced by the insertion of a simple notch filter in the video output of a receiver when the interfering source has a carrier off-set relationship with the wanted source. Filters designed for this purpose introduce some degradation on certain types of picture, but, when the relative level of co-channel interference is greater than −30 dB, an overall subjective improvement is achieved. The technique could be valuable in re-broadcast link applications.

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1. Introduction

The possible degradation of television signals by co-channel interference (c.c.i.) on re-broadcast links (r.b.l.) must be given very careful consideration when such links are being planned. Any measure which can be introduced that reduces the time for which interference is visible on the re-transmitted picture can be of value. Receiving aerial discrimination against unwanted sources is the first line of defence but, particularly in difficult situations, significant interference can still be present for small percentages of the time. This Report describes a series of tests that was carried out with simple notch filters inserted in the video output of a television receiver and tuned respectively to $^{5}/3$ and $^{10}/3$ times the line repetition frequency (approximately 26 kHz and 52·1 kHz respectively). The tests assessed the levels of interference at which a useful improvement in picture grade can be achieved with the filters. The technique is, of course, only applicable in those cases where a base-band signal is available and where the interfering signals have the appropriate frequency off-set.

2. Notch filter design

Figures 1(*a*) and 1(*b*) show the circuits of the notch filters that were used in the tests. They were tuned to resonate at $^{5}/3$ and $^{10}/3$ times the line repetition frequency respectively. The integrated amplifier (Type LH0033) presents a very high impedance to the filter sections. The amplitude responses of these filters are shown in Figures 2(*a*) and 2(*b*). An active notch filter was also tried but, because of non-linear transient effects, the damage to the video signal was more marked. The simple type of filter used is therefore preferred for the application.

The Q factor of both notches and hence their width was chosen as a compromise to make some allowance for the relative frequency drift to be expected between the wanted and unwanted sources whilst not causing undue picture degradation. The current transmitter drive specification allows for a maximum variation of ±1 kHz for the nominal frequency difference between two sources.

Figure 2(*c*) shows an expanded response for the $^{10}/3$ filter. It is seen that the rejection is reduced to between 5 and 6 dB at the limits of the specified relative carrier drift. A shortcoming of the notch filter method is that it is only fully effective if the relative carrier frequency difference between the wanted and unwanted transmissions is maintained with precision.

3. Picture degradation

The picture degradation introduced by the filters is mainly apparent after picture transitions that occur on a number of lines. As an illustration Figures 3(*a*) and 3(*b*) show their responses to a train of line synchronizing pulses. The filters were not group delay corrected but correction would not give much improvement and would result in much more complex circuits. An idea of the streaking effect of the filters can be gleaned from Figures 4(*b*) and 4(*c*). These pictures (Test Card F) may be compared with the unfiltered picture in Figure 4(*a*). These pictures, and those in all the tests, were received directly off air from Crystal Palace. The ripple effect was most apparent on certain types of programme material, for example on captions followed by plain areas, but does not show up well on photographs. On Test Card, in the absence of c.c.i., the filters, on average, produced a Grade 3 subjective assessment (definitely visible but not disturbing) whereas on moving picture material, the average degradation was found to be less than half a grade.

4. The test arrangement

A schematic of the arrangement of equipment for the tests is shown in Fig. 5. Television transmissions from the Crystal Palace transmitter were employed. These are: IBA in Channel 23, BBC-1 in Channel 26, and BBC-2 in Channel 33. The signals were picked up on a directional aerial and passed through a wide-band pre-amplifier. The combination of signals was added to a local oscillator signal in a mixer diode: the frequency of the oscillator was 24 MHz plus the offset. The mixer non-linearity produced, amongst other components, the spectrum of the Channel 23 signal superimposed upon that of the Channel 26 signal with the desired offset. The output from the mixer was applied to the input of a standard television receiver tuned to Channel 26. The system thus simulated a wanted signal (BBC-1) with offset c.c.i. signal (IBA). The relative level of the two signals was set by altering the level of output from the oscillator and measuring the signals with the spectrum analyser. Either notch filter or the condition without a filter could be switched into the receiver video output which was then applied to a picture monitor for observation.

5. Subjective tests

A series of subjective tests was carried out in which participants viewed colour pictures on the monitor, with and without filters, at several levels of c.c.i. Both programme material (as broadcast at the time) and Test Card F were used. Participants were asked to assess the picture degradation on the six point impairment scale.

Grade	Impairment
1	No impairment
2	Just visible
3	Definitely visible but not disturbing
4	Somewhat objectionable
5	Definitely objectionable
6	Unusable

The first set of tests involved the observation of programme material and nineteen people assessed degradation with and without filters at c.c.i. levels of −20, −25 and −30 dB, and also in the absence of c.c.i.

The second set repeated the observations with Test Card F. Eight people took part in this set. For most of the observations the frequency offset of the unwanted signal was set at the resonant frequency of the filter in use, but a limited number of observations were made at a frequency of 1 kHz below the filter resonance.

6. Results

The results of the subjective tests with the $^{5}/3$ and $^{10}/3$ notch filters are summarised in Figures 6(*a*), 6(*b*), 8(*a*) and 8(*b*). The plotted points represent mean gradings averaged over the observers. Root-mean-square deviations are given in brackets beside the plotted points as a qualitative guide to the difficulty in the assessment of the grades and the conditions where the greatest diversity of opinions amongst observers occurred.

Where the trend of mean grade with c.c.i. (measured in dB) is substantially linear best fit lines are drawn in. Otherwise trend curves have been sketched. The effect of moving the offset frequency by 1 kHz from the filter resonance is to remove almost all the benefit as can be deduced from the filter response curves. This was substantiated by supplementary tests using both filters and with the c.c.i. at −25 dB.

7. Discussion of results and conclusions

The results illustrate some of the difficulties encountered in subjective testing. For example, there is a large spread of opinion regarding the degradation introduced by the filters when there is no c.c.i. and when a static picture such as Test Card F is employed. With typical programme material opinions are more in agreement that little degradation due to the filters alone is observed. It is unlikely that the agreement could be improved by using more observers. The important differences between tests using different types of material are notable and these are known to apply to all sorts of subjective experiments involving television pictures.

The success of the technique in reducing the visible effect of c.c.i. relies on the precision of the relative offset frequency. In assessing the usefulness of the technique in particular circumstances this fact must be taken into account.

It seems safe to state that, with precision offsets, an improvement of between one and two grades can be obtained when the c.c.i. is at about −20 dB or worse. At a c.c.i. level of −30 dB or less the improvement is small and the possible degradation due to the filters on some types of programme material means that the technique is not then beneficial. If possible, an automatic means of switching filters out when c.c.i. falls to below −30 dB should be employed. With this proviso, and the maintenance of frequency stability, the technique can be useful in reducing the visible effects of c.c.i. Figures 7(*a*), 7(*b*), 9(*a*) and 9(*b*) give an approximate idea of the visible improvement gained with c.c.i. at the −25 dB level.

SMW/HJC

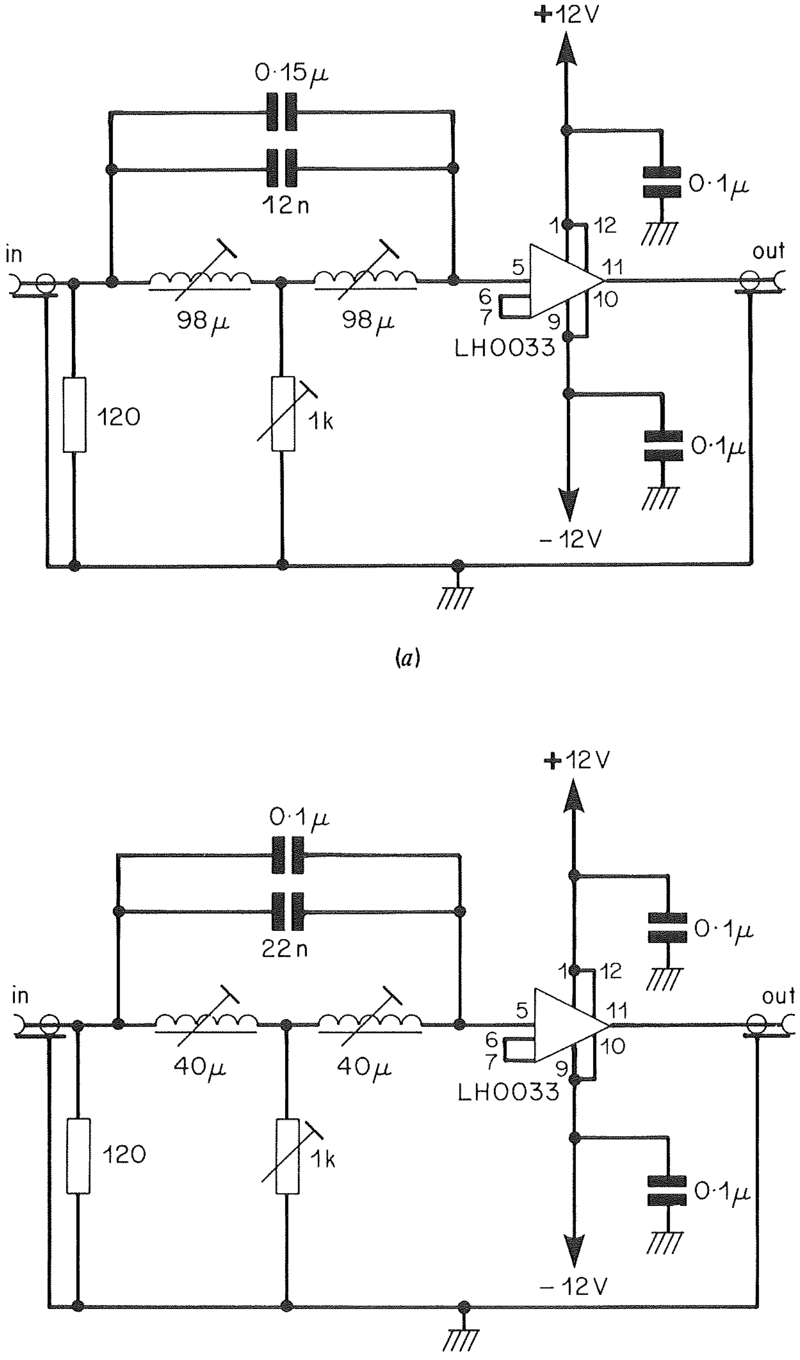
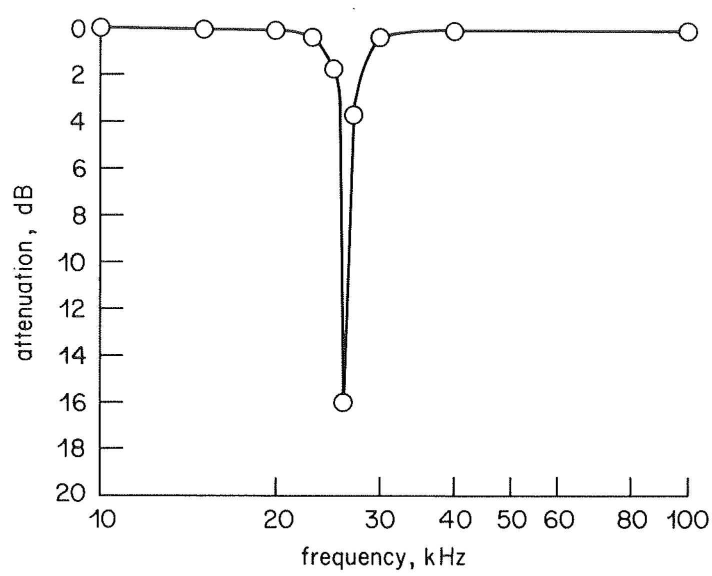
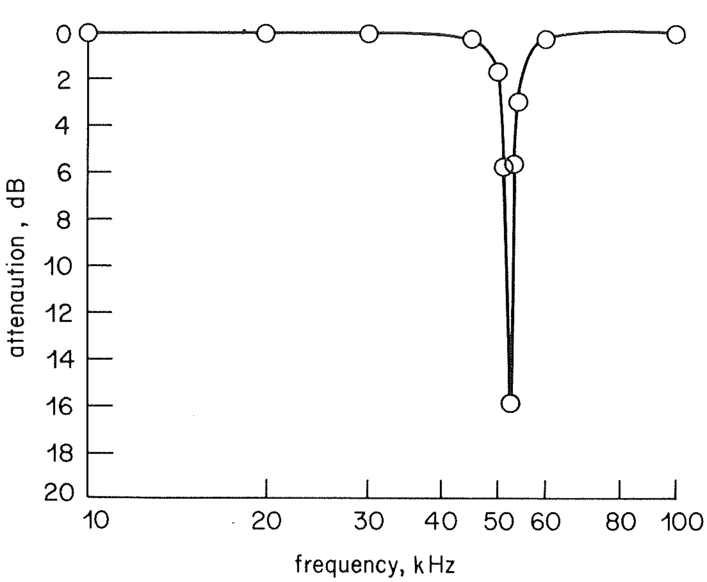


Fig. 1

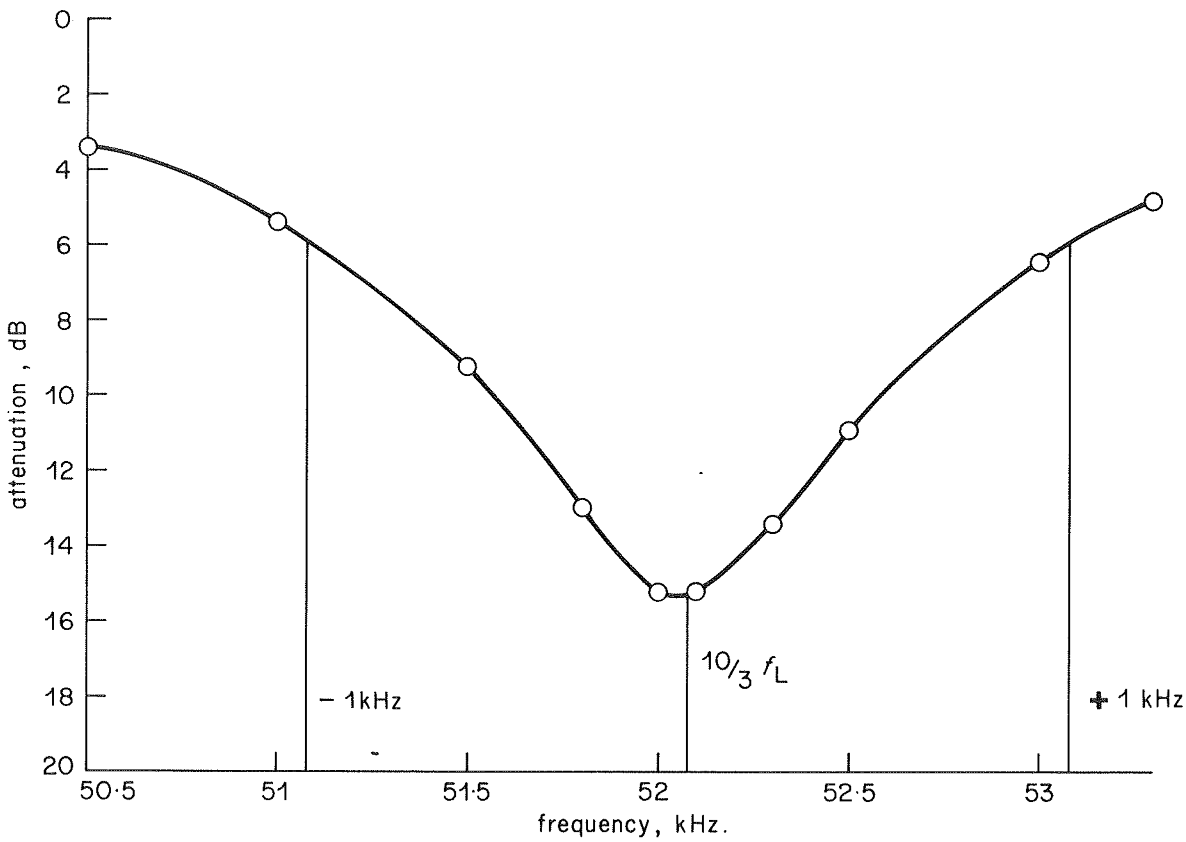
(*a*) Circuit of $^{5}/_{3}$-times-line-frequency notch filter (*b*) Circuit of $^{10}/_{3}$-times-line-frequency notch filter



(*a*)



(*b*)

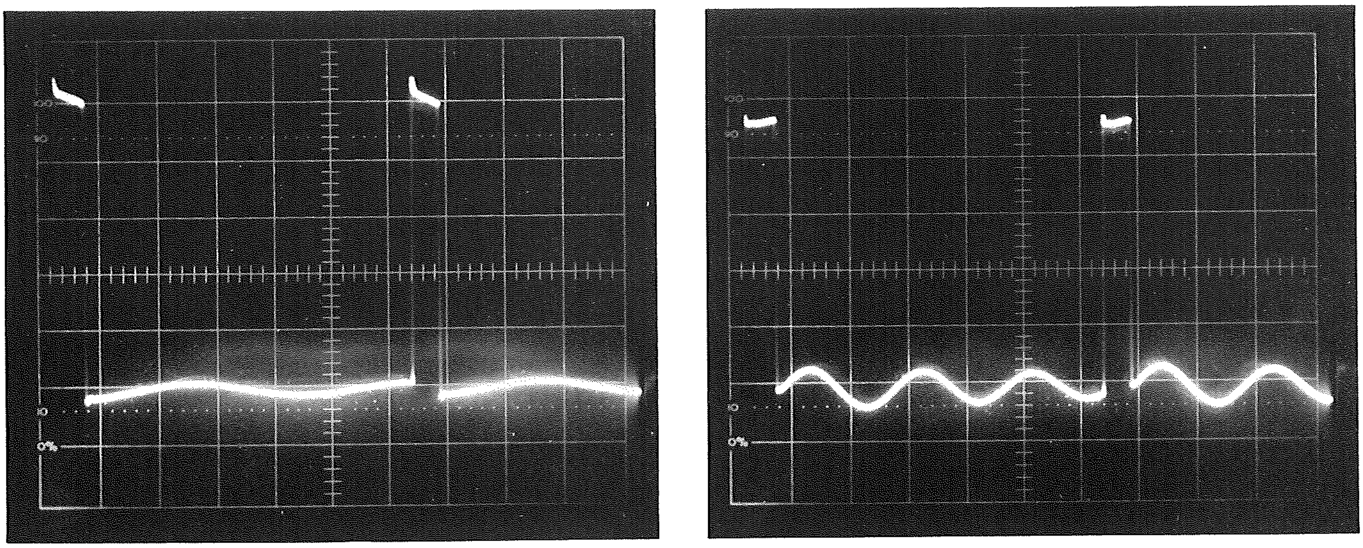


(*c*)

Fig. 2

(*a*) Amplitude response of 5/3 notch filter (*b*) Amplitude response of 10/3 notch filter

(*c*) Expanded response of 10/3 notch filter near 52 kHz



(a) (b)

Fig. 3 - Responses of filters to train of line synch. pulses
(a) $^{5}/_{3}$ filter (b) $^{10}/_{3}$ filter

(a)

Fig. 4
(a) Unfiltered Test Card F received from Crystal Palace without c.c.i.

Fig. 4
(b) Test Card F after $^{5}/3$ notch filter; no c.c.i.

(b)

Fig. 4
(c) Test Card F after $^{10}/3$ notch filter; no c.c.i.

(c)

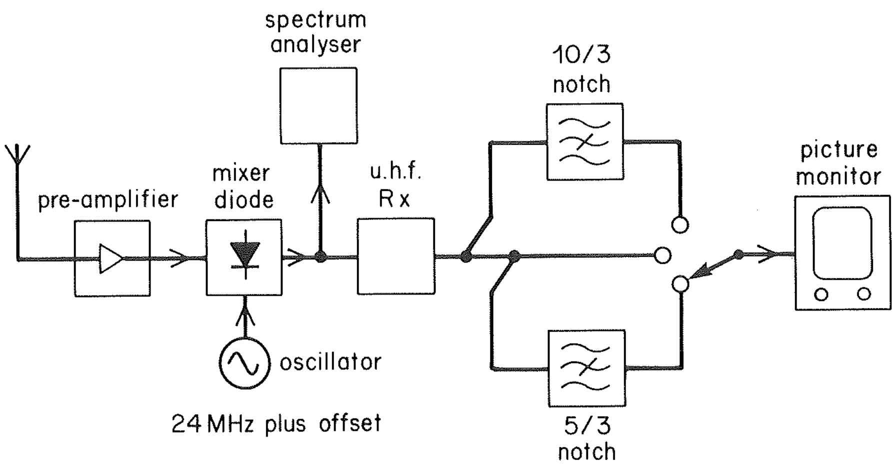
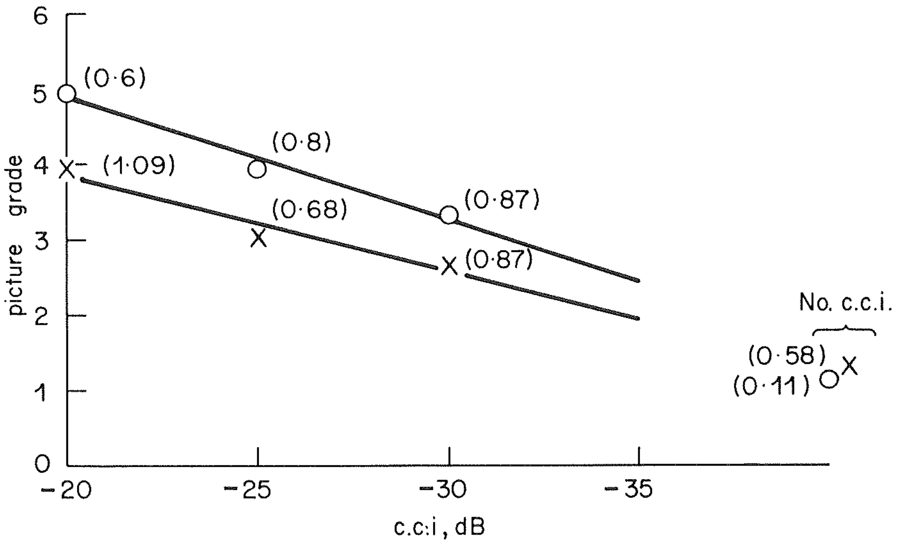
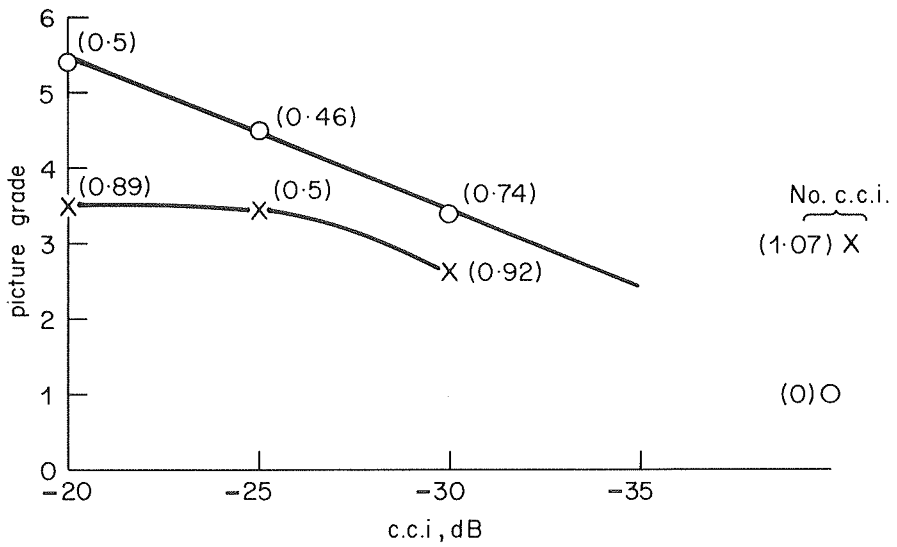


Fig. 5 - Schematic of test arrangement



(*a*)



(*b*)

Fig. 6

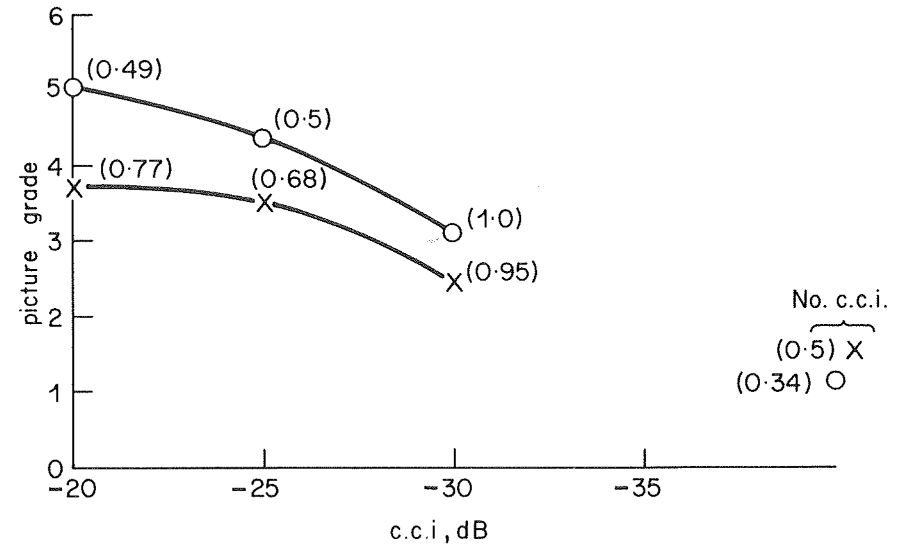
(*a*) Picture grade assessment with c.c.i. on programme material. 5/3 line offset O without filter X with filter r.m.s. deviation (0·6)

(*b*) Picture grade assessment with c.c.i. on Test Card F. 5/3 line offset O without filter X with filter r.m.s. deviation (0·5)

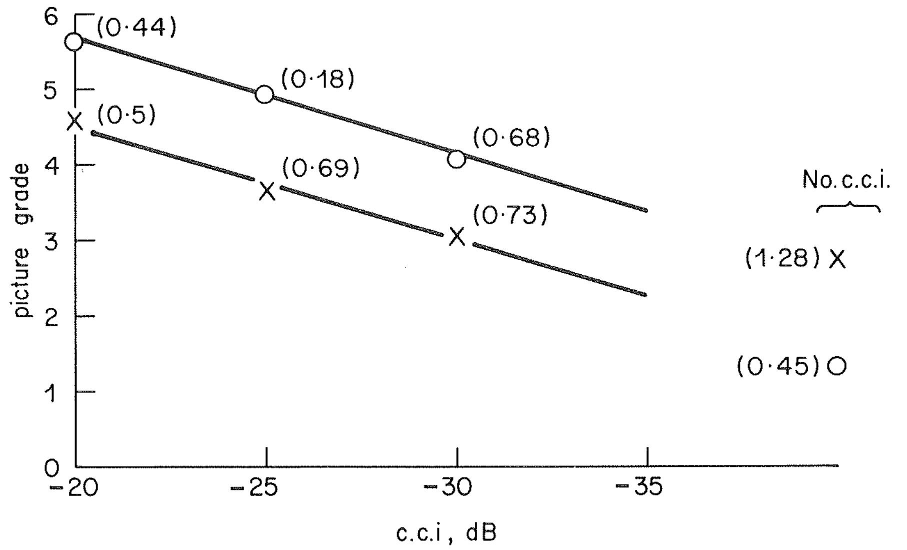
(*a*)

(*b*)

Fig. 7
(*a*) $^5/3$ line offset c.c.i. on Test Card F at −25 dB. Without filter
(*b*) $^5/3$ line offset c.c.i. on Test Card F at −25 dB. With filter



(a)

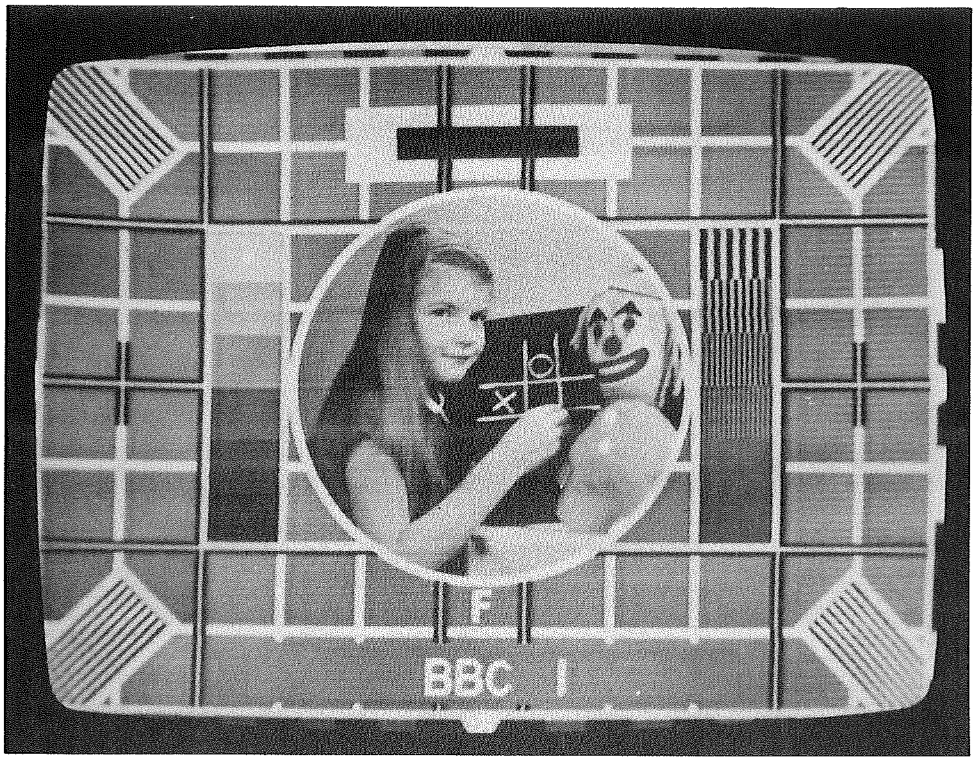


(b)

Fig. 8

(*a*) Picture grade assessment with c.c.i. on programme material. $^{10}/3$ line offset O without filter X with filter r.m.s. deviation (0·49)
(*b*) Picture grade assessment with c.c.i. on Test Card F. $^{10}/3$ line offset O without filter X with filter r.m.s. deviation (0·44)

(*a*)



(*b*)

Fig. 9
(*a*) $^{10}/_{3}$ line offset c.c.i. on Test Card F at −25 dB. Without filter
(*b*) $^{10}/_{3}$ line offset c.c.i. on Test Card F at −25 dB. With filter

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